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ABSTRACT

The Contact Action Space (CAS) of an individual, or group of individuals, has a significant impact on the location of activities and the organization of the use of space. Beginning with the most basic components of a CAS, the individual behavior pattern element is developed, and operational variations affecting alignment and configuration are considered. Five basic measures of a CAS size, density, eccentricity, orientation, and magnitude are calculated and employed to interpret the nature of and changes in a behavior pattern and the associated CAS of a group of 50 individual households during a five year period. The result of the application of CAS analysis to the study of these behavior pattern changes suggest that the concept of contact action space is a useful tool for behavioral studies and has particular application to planning and potential land use research. (Author/RC)

AN IMPLEMENTATION OF THE ACTION SPACE CONCEPT IN BEHAVIORAL ANALYSIS

The study of spatial behavior and its relations to the landscape is a central theme of human geography. A variety of conceptual and analytical devices has been employed in recent years to facilitate the understanding of these man-land-behavior relations and to provide insight into their causes and consequences. One of the more recent concepts employed in this capacity is that of action space.

While interest in action space as a geographic concept has been increasing during recent years, research concerned with it and closely related topics of human behavior has proceeded along two fronts. On the first, action space has been defined and studied as a potential area in which a household unit may conduct all activities, i.e., a potential area of action. This line of development has tended to be largely theoretical because of difficulties in operationalizing a potential (not actual) region.[1] On the second front, individual activity patterns, such as journey to work, have been studied in great detail by a number of researchers. These studies have dealt with actual, empirically derived, behavior patterns but have only been concerned with individual types of behavior.[2] Together works in these two lines of development have contributed substantially to the understanding of human spatial behavior. However, there has been very little work concerned with the areas in which all activities of a household or group actually occur, i.e., an actual contact action space. This absence is a weakness in both the understanding of human behavior and the state of development of action space as a conceptual/empirical device for the study of behavior.

Accordingly, this paper is concerned with action space on an actual (not potential) contact level as it applies to the study of all regularly occurring activities of households. Its purpose is to provide 1) a conceptual and operational definition and model of an actual contact action space (CAS) which can graphically represent activity patterns and can, therefore, be utilized in the study of existing human spatial behavior, 2) a method of estimating certain CAS parameters, i.e., the perimeter, alignment, area, etc., and 3) an application of the contact action space concept and model to analysis and comparison of change over time in the activity pattern of a group of households. The approach, thus, focuses on determining the spatial nature of contact action spaces and on their application to the description and measurement of certain basic characteristics of spatial behavior patterns.

Contact action space as a conceptual and empirical device for behavior study has both theoretical and analytical utility. On the theoretical level, a CAS image of individual or collective (multi-family) behavior provides a view of actual spatial activities that enables consideration of the nature, causes, and consequences of existing activity patterns. On the analytical level, although there are many applications of CAS analysis, a prime utility derives from the fact that it facilitates comparison of different behavior patterns on a qualitative basis via the contrast of the graphic representations and on a quantitative basis via the difference in the sets of CAS measurements (values of parameters). From these comparisons, a greater understanding of behavior patterns, an analysis of change over time in one single action space or collective group action space, and interpretation of impact of behavior patterns are possible.

Evolution of the Action Space Concept

The concept of action space as used in geography[3,4] has a fairly well established background in the field of psychology. The idea of an action space a an area of activity is derived from the work of Lewin[5] who first elaborated on the principles of definable fields of behavior for individuals. It was from these fields of behavior that the concept of life space and finally action space was developed.

Lewin's fields of behavior can be conceived of as areas on individual geometric planes or dimensions located in a multi-dimensional universe. Within this universe, there is one dimension for each possible type of activity in which a person can engage. The area of field on a dimension corresponds to the actual range of conduct of the individual in a specific type of activity. The combined areas on all dimensions in which a person locates and moves are the life space of that individual. The life space of a person is, therefore, a combination of the ranges of physical, emotional, and psychological activities as they are selected and engaged in by the individual in the universe.

The notion of such a space and its component dimensions was further refined by others working in psychology[6] and was introduced into geography by Wolpert who coined the term "action space."[7] In this first geographical article concerned with the concept, Wolpert provided four definitions for the term action space:

1) "That part of the limited environment with which the individual has contact."

2) "The perceived state of the environment."

3) "The immediate subjective environment."

4) "The set of place utilities which the individual perceives and to which he responds."

These four definitions suggest the existence of two basically different types of action space, both of which appear to correspond to areas on certain different dimensions of Lewin's life space. The first of Wolpert's definitions, being concerned with an action space defined by the actual contact of an individual, refers to an area on a life-space dimension in which a person conducts physical spatial moves, i.e., actual behavior. The second, third, and fourth definitions are concerned with an action space defined by the extent of an individual's knowledge of the environment, i.e., a potential area of action or potential action space (PAS). This perceived or potential action space, based on all the inaccuracies resulting from imperfect knowledge, bias, and errors in perception, refers to an area on Lewin's dimension in which a person makes mental moves and choices, i.e., the landscape as it is perceived and where behavior may occur. Wolpert did not elaborate on or develop the distinction between these two different types of action spaces because the general idea of such a space was sufficient for his interest in migration.

Since this first work which established the notion of action space in geography and which served as a springboard for subsequent studies, the distinction between actual contact action space and perceived or potential action space has been largely unexplored.[8] Nevertheless, the distinction between these two areas--the contact and the perceived action spaces--can be seen clearly in the fact that the part of the environment with which the individual has contact is not necessarily the same as the perceived state of the environment (the area of which he has knowledge). In fact, the perceived state (area) of the environment may be quite a bit larger than the area with which the individual actually has physical/visual contact.

Set notation enables the expression of this relationship as a partial inclusion of three sets. If U is the set of all points, the Universe, P is the set of all points perceived, and C is the set of all points contacted by the same person in the universe U, then the expression

1) $C \subset P \subset U$

is defined to be the set of all contacted points contained in the set of all perceived points which are contained in the set of all possible points, i.e., C, therefore, represents the set of all points which exist and which are both perceived and contacted (see Fig. 1).

The zone of all contacted points, denoted here as contact action space, is defined as an area in which all the regularly occurring activities of a household or individual are conducted. This zone necessarily includes the transportation links essential for access from the principal node (household), PN, to each activity point, A, and any intervening area of physical or visual contact adjacent to an activity point or transit links.

This definition of exactly what elements constitute a CAS means that the set of regular activities and its area does not actually refer to all the points that an individual or group has ever come in contact with or all the points with which an individual interacts on any given day. Such a set of total contact points would be impossible to compile, and it would probably be of little value because of the potentially large random components interjected by casual one-time occurrences which might obscure more significant perennial patterns. Instead of consisting of all points ever contacted, CAS is the set of points which the individual regularly (at intervals suitable to the nature of the specific activity) encounters in the conduct of his normal pattern of activities.

A Conceptual and Operational Model of Contact Action Space

Conceptualizing and operationalizing the idea of a contact action space for the purpose of behavior analysis can be accomplished through the formulation of a model based on the most elementary behavior pattern component, the individual activity points or elements. The set of these elements, when aggregated, constitutes the activity pattern which is the basic structure of the CAS of an individual. This geometric structure actually forms the backbone of the CAS and can be expressed in a series of terms such as

2) (2,2), (4,2), (3,3), (2,4), (4,4).

Each term in Statement 2 gives the relative coordinate location of one of the activity points or the principal node of the activity pattern in Figure 3.

The CAS area associated with an activity pattern such as in Figure 3 and Statement 2 can be modeled by drawing a line delineating an area enclosing this geometric structure and excluding all points not involved in the behavior pattern from the CAS area. The assumptions necessary for this process are:

1) There exists a surface, "N", the physical landscape, on which all the activities of a household occur. "N" is a normal linear matrix surface of a Banach space.[9] A transport network dense enough to permit direct access from any point to any other point exists on "N".

2) The distance and direction of each activity point "A" from the principal node (homesite) "PN" can be measured.

3) CAS is a finite closed area on "N" which consists of the locations of all the regularly occurring activities of an individual (the activity points) "A", and the transport routes "TR" necessary for movement to each activity from the principal node. Also included in CAS are the intervening areas "IA" of visual/physical contact adjacent to each transport route and alpha areas "α" of visual/physical contact adjacent to each activity point.

4) The size of the physical/visual contact areas (α and IA) adjacent to any activity point and at any point along transport routes are a function of the frequency and intensity of exposure at those points. During any given finite time period, the CAS and its structure remains unchanged and, therefore, determinable because the individual, the environmental structure and composition, and the individual's level of knowledge of the area are unchanged.

5) Only single purpose/destination trips occur.[10]

Under these assumptions, CAS is a series of finite areas "α" of visual/physical contact surrounding each element $A_1, A_2, \ldots, A_n$ of the activity pattern. Each "αA" is connected to the homesite by a narrow corridor of visual contact area "IA" surrounding each of the transportation routes of the pattern. Figure 4 illustrates a hypothetical CAS generated for the activity pattern of Statement 2. A general form of a CAS model can thus be specified by the statement:

3) $CAS \varepsilon \; \alpha A_1, \; \alpha A_2, \ldots \; \alpha A_n + \; PN +$
$TR_1[(1^L), (2^M), (3^N)] +$
$TR_2[(1^L), (2^M), (3^N)] + \ldots$
$TR_n[(1^L), (2^M), (3^N)].$

where: A is an activity point,
α is the visual contact area surrounding each activity point,
TR_1 is the transport route from PN to A_1, and
(1^L) is the width of the IA area at point 1 along any axis.

Statement 3 describes human contact areas on a conceptual and operational level by subsuming and precisely specifying the set of all points or areas whether physically or visually contacted and excluding all other points. It thereby provides a notational definition of CAS and an organizing, internally relating framework for studying all the components of a CAS as well as the collective structure in general. In so doing, it meets the first objective of this paper. Specifically, it is a conceptual model of contact action space which is appropriate for studying human spatial behavior.

This model can be operationalized for a particular household by substituting actual values for the two types of information on human spatial behavior patterns: 1) location and 2) visual area size. Table 1 lists data on the behavior patterns of an individual Chicago household. The data consists of the coordinates for a set of five activity points, the size of the contact zone at each point, and the mean size of contact zone along each axis.

The specific operationalization and visual modeling procedure involving this data has two stages. The first stage consists of the information on location of activities, the "A" terms of 3, being converted into relative coordinate locations, with the principal node at the origin, and the plotting of these points in their proper relation. This stage results in a basic activity structure such as shown in Figure 5, where each activity is connected to the "PN" by the transport routes. The second stage in the visual modeling process is the conversion of the measured values of the "[illegible]" and "IA" areas into areas at the scale of the visual model or map and the placement of each "[illegible]" and "IA" area at the appropriate "A" or "TR" location. This stage results in a fairly complete representation of the precise physical/visual contact zone of the individual. Figure 6 portrays the CAS corresponding to the data of Table 1 and calculated in the above manner according to the relation specified in Statement 3. Figure 6 is, therefore, actually a map of the behavior and areas of contact of the individual. This constitutes an illustration of the use of CAS in the study of behavior.

This procedure of numeric and graphic modeling of a CAS is dependent largely on the availability of a significant quantity of very specific data - namely the activity locations and visual contact area sizes. Of these, the size of the visual contact area of an individual at an activity point or along an axis is relatively difficult and tedious to obtain. Therefore, the necessity for this area data is a drawback to the above method of detailed CAS modeling. Accordingly, a procedure for approximating a CAS using only the comparatively easily obtainable location data is desirable.

The presentation of such a method is the second objective of this paper.

Action space Approximation

Any action space approximation is dependent upon activity location data because it is not possible to map and model activity patterns if the locations and structure are not known. It is possible, however, to get by without specific visual contact zone data because such areas can be accurately simulated.

The approximation and physical delineation procedure utilizing this data is derived from the works of Everett as adapted by Lidstone.[12] A modification of their original interpolation procedures enables the calculation of the CAS area, including the appropriate points and excluding all others, and the calculation and plotting of a line delineating the exterior of the CAS. The computer routine adapted for delineation of the CAS is an iterative process involving the simultaneous solution of three equations for each iteration.

These three equations, since both line and area are specified by a common set of points, yield a line length (4) and an area value (5) which can be combined in an index to provide a configuration for the CAS and an index of accuracy (6) of that configuration. The index of accuracy is based on the conformance of the approximation alignment to the optimum of Statement 3. The validity of the index of accuracy has been further established by testing the resultant configuration against emperically derived CASs for the exact same household calculated with complete sets of data. The three equations are:

1. A line "L" connecting all the activity points of a given activity pattern (defined by coordinates) in sequence in terms of their relative locations.

4) $L = d(A_1, A_2) + d(A_2, A_3) + \ldots + d(A_{n-1}, A_n)$

where $d(A_1, A_2)$ is the distance from activity point A_1 to activity point A_2.

2. An area $\bar{A}$, the area enclosed by line L.[13]

5) $\bar{A} = 1/2\ (X_1X_2 + X_2Y_3 + \ldots + X_{n-1}Y_1 - Y_1X_2 - Y_{n-1}X_n - Y_nX_1)$

where: X_1Y_1 is the coordinate location of A_1 activity point.

3. A series

6) $B(I) = L + \bar{A}$

where: L and $\bar{A}$ are inversely related,[14] and, therefore,

B(I) is a finite series whose values range from $0-\infty$.

Each B(I) term is the sum of the $L + \bar{A}$ of an iteration and is an index which indicates how accurately that delineation represents the optimum, Statement 3.[15]

Before the iteration process begins, the locations of all activities are converted into coordinates, such as those on Table 1, and connected by one single line into a perimeter. In the first iteration of this process, the line that has been drawn connecting all the activity points and the enclosed area are measured. Their values are converted to a common index and added together to create the B(I) term for that iteration. The line for that first iteration is the shortest possible connecting all the activity points. The area associated with the first iteration is the largest possible area of action for the given activity pattern since line and area are inversely related and since the area includes all activity points and all internodal and interaxial areas. In this iteration, the B(I) value is large because of the large $\overline{A}$ component (see Fig. 7, a hypothetical illustration of the first stage of a delineation where L is at its minimum, $\overline{A}$ is at its maximum, and B(I) is greater than its minimum value).

The routine continues with the second and all subsequent iterations, each of which begins by reducing the $\overline{A}$ product of the previous stage by one unit and computing the appropriate longer line length and B(I) terms for each smaller area until the final iteration is reached. The final iteration has the smallest $\overline{A}$ and largest L possible for a given activity pattern because the line trace is immediately adjacent to the activity points (see Fig. 8, a hypothetical illustration of the final stage of delineation, where L is at its maximum, $\overline{A}$ is at its minimum, and B(I) is greater than its minimum value). The B(I) value of this final iteration is large because of the large L component.

Neither the first nor last iteration provides a good delineation of CAS because, in the first case, non-contacted interaxial and internodal areas are included and, in the last case, actually contacted physical/visual and IA areas are excluded. Between these two extremes are a number of iterations, each with L, $\overline{A}$, and B(I) values, that represent a delineation. One of these interim iterations is the best (optimum) approximation of CAS as defined in Statement 3 because it specifies a line and area which include points that are physically/visually contacted and excludes those that are not.

The precise identification of the iteration which best approximates the CAS of Statement 3 is difficult, but it appears to be in the vicinity of the lowest B(I) value. This lowest B(I) iteration may be the best approximation of Statement 3 because, as the above routine proceeds from the first iteration to the last, the larger $\bar{A}$, including non-contacted areas, is declining and L is lengthening, eliminating the uncontacted area. At the lowest B(I) term, the proportional increase in L adds more to the value of B(I) than does the proportional decrease of $\bar{A}$. Up to the vicinity of this point, because L is bound to activity points by its coordinate values, the decreases in $\bar{A}$ and B(I) have been in the interaxial and the internodal areas only (those areas that are uncontacted). The result has been the progressive elimination of non-contacted areas and an improved delineation of CAS. Past the vicinity of this point, a further reduction in $\bar{A}$ is accompanied by an increase in L at an increasing rate and an increase in B(I). This must eventually result in an exclusion of contacted areas as L is drawn closer to the axis and activity points. The lowest B(I) iteration value, then, appears to be in the vicinity of the point where all uncontacted area has been eliminated.

Figure 9 shows a hypothetical delineation of the iteration where L and $\bar{A}$ are at some value other than their minimum or maximum and the resulting B(i) is at its minimum value. This delineation and iteration is intermediate between the delineations and iterations of Figures 7 and 8. It is visually and intuitively obvious that the delineation of the lowest B(I) term (Fig. 9) conforms more closely to the optimum of Statement 3 than does the delineation of the higher B(I) values (Figs. 7 and 8), in that appropriate proportions of physical/visual areas are included and non-contacted areas are excluded. It can be argued that the lowest B(I) term might not represent the precise optimum (by Statement 3) delineation of CAS; nevertheless, it is very likely that the optimum delineation of CAS (where only the contact area is included) is in the vicinity of the lowest B(I) term since progressively, on either side of this iteration, uncontacted points are included or contacted ones are omitted.

The success of this approximation procedure, in accurately representing the actual CAS of a household, can be best evaluated by a comparison of the lowest B(I) delineation with the actual CAS model for a household constructed with a complete set of data. For the purpose of such a comparison, an approximation of the actual CAS of Figure 6 and Table 1 was conducted using Statements 4, 5, and 6. The results (the delineation associated with the lowest B(I) value) on Figure 10 can be compared with Figure 6 and show the efficiency of this approximation system.

The comparison can be briefly summarized as revealing that the approximation yields a basically similar structure and perimeter configuration and, therefore, a basically similar area and line length. The difference between the actual image of a CAS (Fig. 6) and the approximated image (Fig. 10) is the omission of some small areas and the inability to deal with [illegible] and IA variations. Thus, this system of approximation yields a fairly accurate representation of a CAS and in so doing meets the second objective of this paper -- the presentation of a method of approximating the area, perimeter, and alignment of a CAS.

Applications

The real value of any concept or technique such as the contact action space approximation of behavior patterns lies in the success and quality of insights it provides into the phenomenon under study, and this may only be established through the application of that concept or technique to the analysis of actual situations. In this context, an action space composed of and defined by points of activity occurrence rather than potential areas of activity is especially suited to certain specific evaluatable applications. Among these are 1) the revealing of behavior patterns and their regularities,

2) the identification of the areas of impact of these behaviors, and 3) the comparison of change in activity patterns of groups of households through time which may provide insight into the possible effects on behavior of such phenomenon as technology and perceptual value change.

Accordingly, the final objective of this paper is a study of change over time in behavior patterns of fifty Chicago families. These families were interviewed in 1968 and again in 1972 to determine the location of points of conduct of certain activities. Figure 11 shows an abbreviated action space of one of the households within the city of Chicago in 1968, and Figure 12 shows the comparable action space for the same family in 1972. From these two contact action spaces a visual comparison of the differences is possible, and this comparison enables a consideration of the trends in behavior and the factors which affect it as well as a consideration of the impact of behavioral changes on the landscape.

Despite the fact that such inquiries can be conducted on a basis of visual inspection and on an individual level, their results and conclusions have a limited application (they apply only to that household) and are qualitative in nature and, therefore, perhaps imprecise. In contrast to this, results and conclusions, etc., with a more generalized application and of a more precise nature can be obtained by statistical analysis of precise measurements drawn from a group of CASs. This analysis consists of measuring certain parameters (size, density, eccentricity, orientation, and magnitude) of each action space in a group, such as all 1968 action spaces or all 1972 action spaces and calculating and comparing group representative values (mean, mode, and range) for each parameter. These representative values perform two functions: 1) their comparison indicates the differences in nature of the two sets of action spaces and 2) they may be used to reproduce statistically representative graphic images of both sets (a collective CAS for each group). These graphic representations of the two different sets of action spaces would typify the general nature of the entire set of individual CASs, for which its specifications were the representative values, without necessarily corresponding directly to any one individual action space.

Table 2 shows the mean values for the five selected contact action space parameters for the 1968 action spaces and the 1972 action spaces: size, density, eccentricity, orientation and magnitude. Each of these parameters was selected because each deals with an important aspect of CAS and reflects some part of the associated underlying behavior, but their principal advantage is that they are terms in which action spaces are directly comparable and in which they can be considered on a common basis.

Size, the first of these parameters, refers to the linear extent of distance traveled; density refers to the relative dispersion of the elements in the action space and is a measure of the areal extent (or concentration) of behavior and its impact; eccentricity is a measure of the relative directional bias of the action space; and degree of orientation and magnitude are measures of absolute direction and elongation of the activity pattern. Figure 13 shows the graphic representation of the collective CASs for the 1968 and 1972 groups constructed according to the representative parametric values of Table 2. Naturally, these collective spaces graphically possess only a general form and do not contain all of the intricate spatial irregularities of an individual action space as in Figure 11 or 12 because precise location, structure, and contact zone data are not involved. These collective action spaces, then reflect only the predominent size, shape, and alignment typical of their component individual action spaces. An eyeball inspection of Figure 13 shows the obvious differences, but the real dimension and extent of the contrast which may be overlooked is clearly revealed by evaluating the difference of value of each parameter.

Size. Action space size, being simply the size in distance of miles of the links of the activity patterns, is an excellent method of comparison of action spaces and clearly points up a significant difference. Additionally, it has the analytical utility of being a measure of distance traveled and thereby an indication of the mobility of the traveler and of the extent of his influence as a resource and consumer. For the 1968 action space, mode element distance amounted to 42 miles, and for the 1972 action space, the mode element distance is only 24 miles (see Table 2). The difference documents quite clearly that the two action spaces are dissimilar and shows the degree of this contrast which might otherwise, from Figure 3, have been overlooked or underestimated.

Density. Action space density "D" which is a measure of the closeness of elements is given by the formula:

10) $$D = 1 - [\frac{ed}{N}\ 0.1]$$

where: D is density which has a range of values from +1 to -1, where +1 indicates complete compaction and -1 indicates complete dispersion,

N is the number of elements in the action space,

ed is the element distance, and

contrasts 1 and 0.1 are used in the above expression to specify the range of D and to regulate the rate of change of D to a constant proportional function of $\frac{ed}{N}$.

Density, as a measure of interelemental distance, provides information on the area of influence and particularly the degree of concentration of the impact of the action space and its behavior pattern. On Table 2, the densities of the two collective action spaces are whown to be +0.92 and +0.86 respectively. This density contrast documents some of the dimensions of the differences between these two action spaces and reveals that, although both CASs are fairly dense (with complete compaction being 1.0). the 1972 action space is not only smaller (24 vs. 42 miles) than the 1968 action space, but is also more compact. From this, it is possible to conclude that the 1972 action space may have a more intense impact on the area involved than the 1968 action space.

Eccentricity. Eccentricity of an action space "X", a measure of the relative directional bias from the principal node of the activity pattern, is given by the formula:

$$X = \frac{V}{v} \tag{11}$$

where: X is eccentricity ranging from 0 to ∞, as eccentricity increases,
X = 50 indicates extreme elongation,
X = 1 indicates a shape tending toward nearly perfect roundness,
V is the distance to the most distant element from the principal node,
v is the perpendicular distance from the axis of V to the element most distant from that axis.

This measure of the relative directional bias indicates a general area and direction of influence (shape) of the action space. On Table 2 the 1968 action space is shown as having an eccentricity of 2.0 while the 1972 action space has a higher value of 3.0 and is, therefore, more eccentric, having its impact, etc., occurring more in one particular direction than in any other. Once again this parameter documents a contrast, which is somewhat obvious from inspection of the typical graphic images of Figure 13, but whose degree of differences (50% greater) is not obvious.

Orientation and Magnitude. The orientation and magnitude of an action space which are measures of the absolute directional bias and its distance (or extent) are related to each other and are somewhat similar to eccentricity in that they refer to the direction and distance of activities from the principal node. However, orientation and magnitude differ from eccentricity in that they are principally concerned with absolute direction and distance, not with internal (to the action space) relations of several distances and directions. Thus orientation and magnitude indicate the directionality and distance of relations of the action space with areas and elements of its environment, i.e., parts of the city, shopping centers, industrial complexes, etc.

Orientation of an action space is the direction, defined by quadrant alignment 1, 2, 3, or 4, of the longest element distance measured from the principal node. Quadrants are numbered 1, 2, 3, and 4, clockwise from the north and subdivided into 100 parts such that an orientation of 1.50 would represent an axis running northeast from the principal node. The magnitude of an orientation is the distance along the orientation axis to the most distant element. Figure 14 exemplifies the orientation and magnitude of a CAS with an orientation of 2.0 (due east) and a magnitude of ten miles. These two final CAS parameters, showing absolute direction and distance and indicating the direction of the greatest extent of an action space, reveal that both action spaces (1968 and 1972) were very similar with the 1972 CAS having a slightly longer magnitude (Table 2). The similarity shown by these two parameters reflects the obvious visual similarity of Figure 13 but points up the subtle differences in direction, the 1972 action space being slightly inclined in a more northerly direction and slightly in magnitude.

These five measures taken together and the graphic representations of the two sets of CASs (Fig. 13) provide ways of describing collective or individual contact action space for comparisons, but they also may be used in interpreting the subsumed patterns of behavior, their changes, and their consequences and causes. These measures indicate that substantial change has occurred between 1968 and 1972 in this group of families' behavior patterns. Specifically, (from the table) the 1968 CAS is physically almost twice as large, 2/3 as dense, more nearly circular, oriented in a more westerly direction, and has a shorter magnitude than does the 1972 CAS. This comparison means that these families in 1972 tended to conduct their activities closer to home (density +.92) and in a channelized pattern (eccentricity 3.0). Although it did travel farther to its most distant activity (magnitude 15), the distance to all other activities was lower (size 24).

The interpretation of causes and consequences of such a substantial alteration of a behavior pattern inevitably involves the peculiarities of the individual circumstances (both family and environment) and cannot be made out of situational context and without specific detailed evaluation. However, the general categories of influences of such pattern shifts as these two action spaces show may include: 1) changes in environment, 2) increases in individual or group of households' level of knowledge of the environment, or 3) changes in the family or families. These factors, coupled with technological improvement in transportation efficiency either by the introduction of new modes of travel or change in transport routes, could account for the decreasing size and increasing density along with the increased elongation of CAS.

An assessment of the impact on the landscape of such changes in behavior (the consequences) also involves the peculiarities of the individual circumstances and substantial situational analysis. As a result, because of the many complex relations involved, these consequences may be even more difficult to specify and identify than are the causes, but there can be no doubt as to the existence of some impact deriving from the change in location of activities.

Conclusion

The notion of a contact action space, as defined and used in this paper as the area of contact of an individual and delineated by the above method, enables the specification and study of actual behavior areas. By dealing with actual behavior, CAS supports a consideration of causes and consequences of behavior patterns, and, as such, CAS differs from the perceptual or potential action space concept currently in the literature. Approaching the concept of action space from the point of view of areas actually contacted, rather than as an area about which the individual has knowledge, assumes that there is value in looking at actually occurring behavior as well as potential behavior.

In this context, however, studies of CAS are not substitutes for studies focusing on perceived action space, but they can provide complementary information to that attained by research on PAS. The information and knowledge produced by research on actual areas of behavior has theoretical and analytical utility for the understanding of existing behavior patterns, their determinants, and their impact on the arrangement and composition of the landscape. Thus, the concept of CAS is very appropriate and useful as a basis for planning and policy formulation since both of these must, among other things, consider actual current behavior for its own sake and because this current behavior is one of the chief determinants of future behavior. For this reason, planning both by and for the private and public sectors must involve consideration of the actual behavior pattern, and CAS analysis is one method of getting at this pattern by portraying and abstracting certain of its spatial characteristics.

Two problems stand in the way of increased application of CAS. The first is that the use of CAS analysis and the defining of a CAS for a family or group of families are dependent upon the availability of primary interview information. This problem is likely to persist in each CAS application since, in all cases, the availability of information about places of contact is necessary, and this requires fieldwork. In recognition of this first need, and to broaden the base of knowledge of actual behavior patterns, a study of population behavior utilizing CAS analysis and based on data obtained from interviews of over 800 families is currently in process.

The second problem in increased use of CAS is the presently incomplete state of knowledge about the relation of a person's level of exposure to a point and the general size of his physical/visual contact area at that point. This second problem may possibly be eliminated, or at least substantially reduced, in the future since a number of studies currently underway are attempting to develop and calibrate a general relation or identify the direction and magnitude of relations between exposure and size of contact area. From these studies, increasingly accurate estimates of the nature of α and IA area sizes may result. Despite these limitations and because of its ability to be defined precisely and operationalized, CAS has utility on both a theoretical and analytical level for the study of behavior.

TABLE 1

HYPOTHETICAL ACTIVITY PATTERN RELATIVE LOCATIONS
AND α- AND IA SIZES FOR FIGURE 9

Point #	Activity	Coordinates	Area Diameter	IA mean width along PN - A axis
PN	Homesite (principal node)	10, 8	2 miles	200 feet
1	Work	15, 13	1 mile	100 feet
2	Purchase of Shopping Goods	9, 7	1/2 mile	50 feet
3	Purchase of Durables	10, 11	1/2 mile	50 feet
4	Social Contacts	12, 9	1/2 mile	50 feet
5	Location of Service Contacts	11, 10	1/2 mile	50 feet

TABLE 2

COMPARATIVE ACTION SPACE CHARACTERISTICS 1968 AND 1972

	Size	Density*	Eccentricity	Orientation	Magnitude
CAS (1968)	42	+.86	2.0	4.30	13
CAS (1972)	24	+.92	3.0	4.35	15

*Density computed for 30 activities for each CAS and with ed (size) value of 42 and 24 miles respectively.

Footnotes

1. Frank E. Horton and David R. Reynolds, "An Investigation of Individual Action Spaces: A Progress Report, "Proceedings of the Association of American Geographers, I, 70-75, 1969.
2. F. S. Chapin, Household Activity Systems -- A Pilot Investigation (Chapel Hill: University of North Carolina, Center for Urban and Regional Studies, 1964), pp. 13, 17, 25-37.
3. Frank E. Horton and David R. Reynolds, "Action Space Formation: A Behavioral Approach to Predicting Urban Travel Behavior, "Highway Research Record, 1970.
4. Gerald Rushton, "Analysis of Spatial Behavior by Revealed Spatial Preference," Annals of the Association of American Geographers, LIX, 391-400, 1969.
5. Kurt Lewin, Field Theory in Social Science (New York: Harper and Row, Inc., 1951), xi, 51.
6. J. R. Day, "Life Space and Social Action," Journal of Educational Sociology, XXXVI (1962), 145-149.
7. J. Wolpert, "Behavioral Aspects of the Decision to Migrate," Papers and Proceedings of the Regional Science Association, XV, 159-169, 1965.
8. M. E. Eliot Hurst, "The Structure of Movement and Household Travel Behavior," Urban Studies, VI, 70-82, 1969.
9. A normal linear surface is a surface on which is defined a function which assigns to each arbitrary element X on the surface a real number $|| x ||$ such that:

$$1)\ || x || \geq || x || = 0 \leftrightarrow x = 0;$$

$$2)\ || x + y || \leq || x || y ||;$$

3) $\|\alpha x\| = |\alpha| \, \|x\|$,

and therefore it is a surface on which there is a satisfactory notion of distance from an arbitrary element to the origin, i.e., places can be referenced. For further elaboration see George F. Simmons, Introduction to Topology and Modern Analysis (New York: McGraw-Hill, 1963), p. 81.

10. Actual travel patterns suggest that multipurpose trips to points at gr[illegible] distances are very infrequent and those that do exist typically involve only stops that tend to be made at the extreme end of an activity axis.

11. The size of such a visual contact area at a point or in a zone along a route of travel is related to the quality of exposure at that point or along the axis. The nature of this area has been investigated in a number of psychological studies and explored in an unpublished research paper, "Toward a Theory of Human Contact Area" by Gary Higgs, Michigan State University, July 1972.

12. G. J. Lidstone, "Notes on Everett's Interpolation Formula," Edinborough Mathematical Society Proceedings, Series I, 1920-1923, XXXIX-XL (1920), 21-26.

13. The formula for $\bar{A}$ is derived from a general polygonal area formula appropriate for any non-intersecting closed polygon presented in: J. Casey, A Treatise on the Analytical Geometry of the Point, Line, Circle, and Conic Sections (Dublin: University of Dublin Press, 1893), pp. 10 and 79. The formula is especially appropriate for action space delimitation because, although the contact action space does not have necessarily straight lines, its boundaries and its borders can be resolved accurately into a series of finite length straight lines

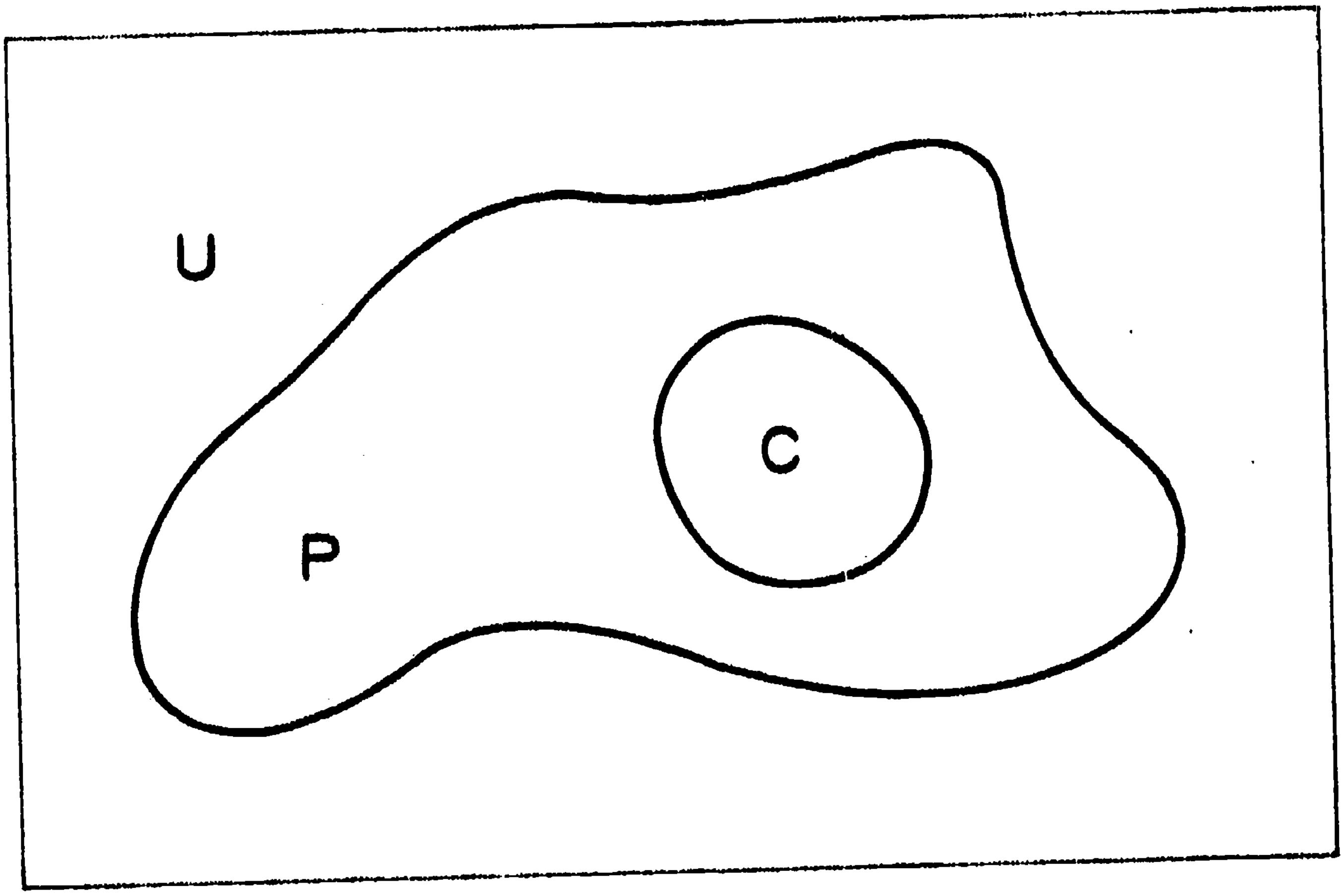
from the coordinates which specify the location of activities of a household. With special allowance made for the circular nature of a physical/visual contact zone around each activity point, the remaining exteriors of action spaces can be represented accurately by an "N" -sided polygon. This formula in operation requires the addition of products of coordinates on negatively sloped positive sign lines and the subtraction of products of coordinates on the positively sloped positive sign lines.

14. Normally an area and a line enclosing it tend to be proportionally related, i.e., if the area is doubled, the line is increased by some amount. In the case of this delineation, the relation between the area $\bar{A}$ and the line L enclosing it is inverse because the objective is to closely outline a structure having a considerable spatial extent (linearity) and a small area. The inverse relation of an area and a line enclosing it is based on the principle of calculus which states that a line may enclose a maximum area but no minimum. Examples of this inverse relation can be seen in the sine $\frac{1}{x}$ curve and the Warsaw circle.

15. B(I) is an index of accurate delineation of CAS because only at some point, one iteration (one delineation) is CAS precisely defined. This point (delineation and iteration) is represented by a B(I) term, as are all other iterations and delineations. The B(I) term indicates which iteration corresponds to the best delineation of CAS because this optimum is the delineation in which all included points are in $\bar{A}$ and all excluded are beyond L. Since this point will not be where either $\bar{A}$ or L is very large or very small but where they are at medium values, and since $B(I) = \bar{A} + L$ and $\bar{A}$ and L are inversely related, this will be in the vicinity of the lowest B(I) term.

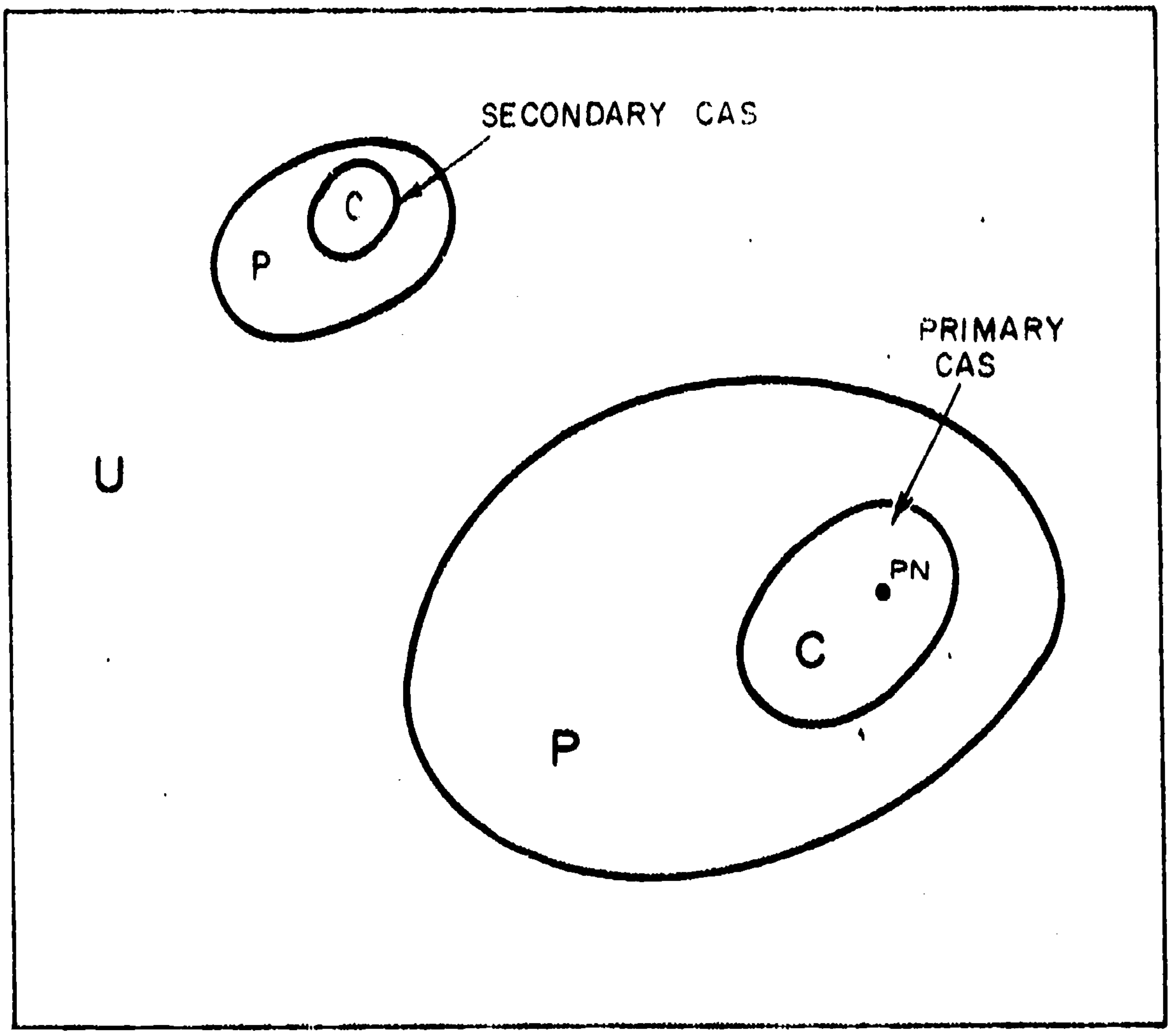
"Action Space in Behavioral Analysis"

FIGURE 1



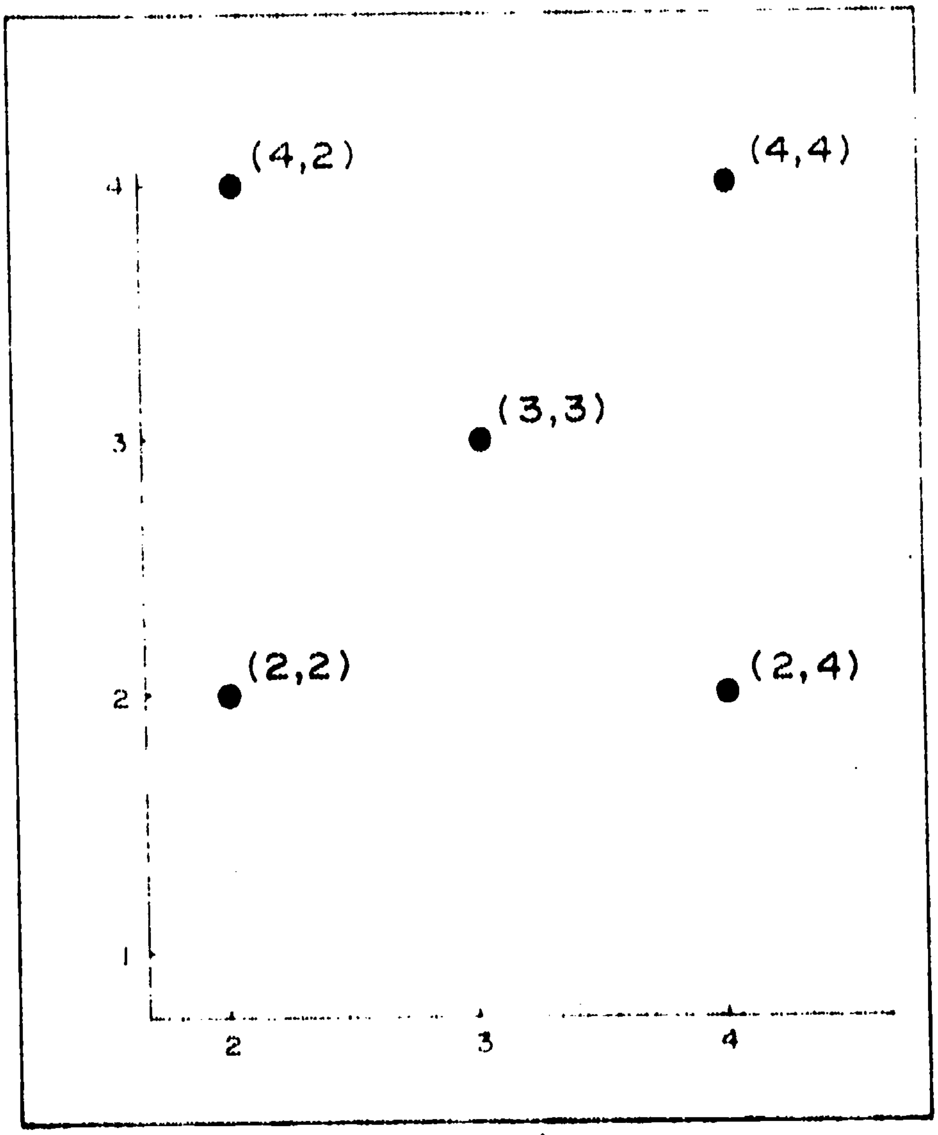
"Action Space in Behavioral Analysis"

FIGURE 2



"Action Space in Behavioral Analysis"

FIGURE 3



"Action Space in Behavioral Analysis"

FIGURE 4

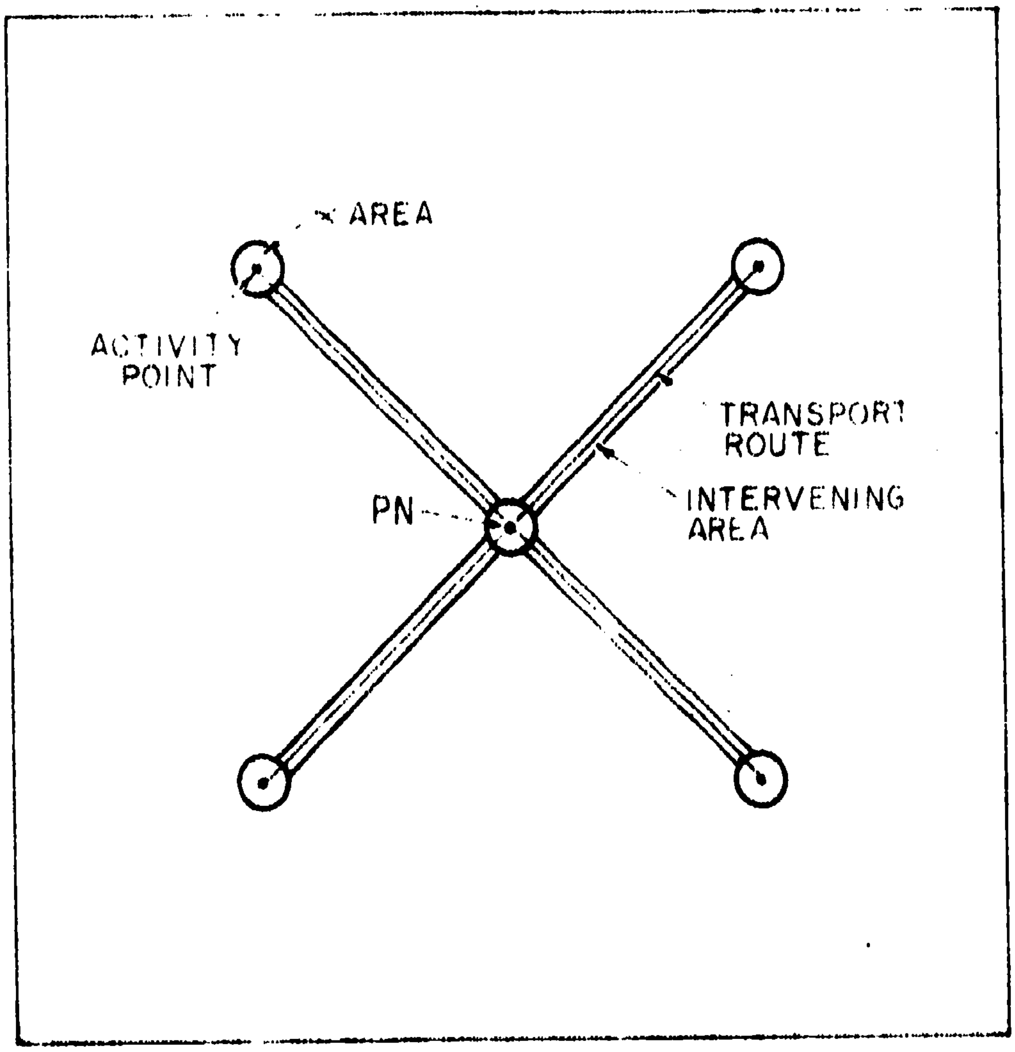


FIGURE 5

"Action Space in Behavioral Analysis"

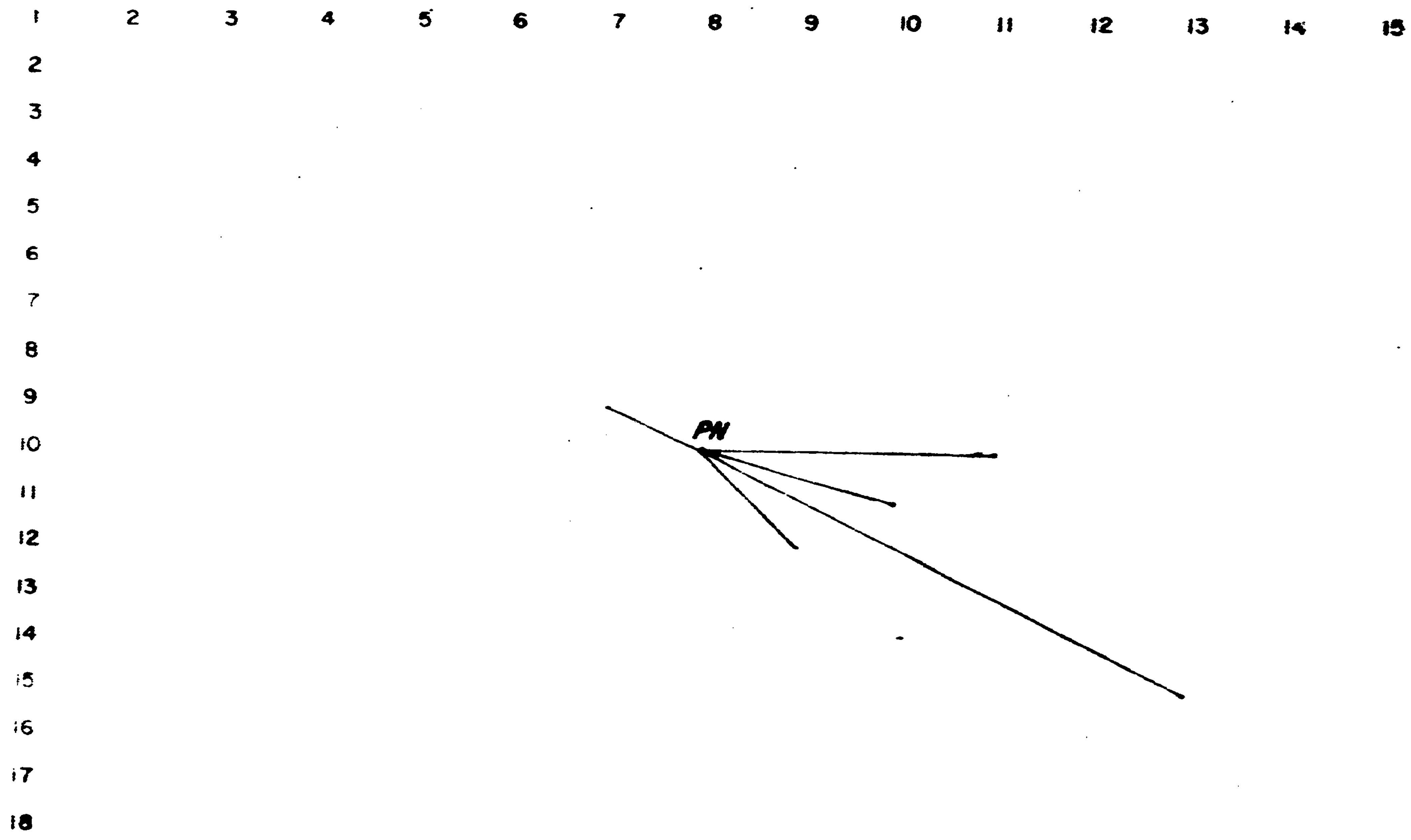
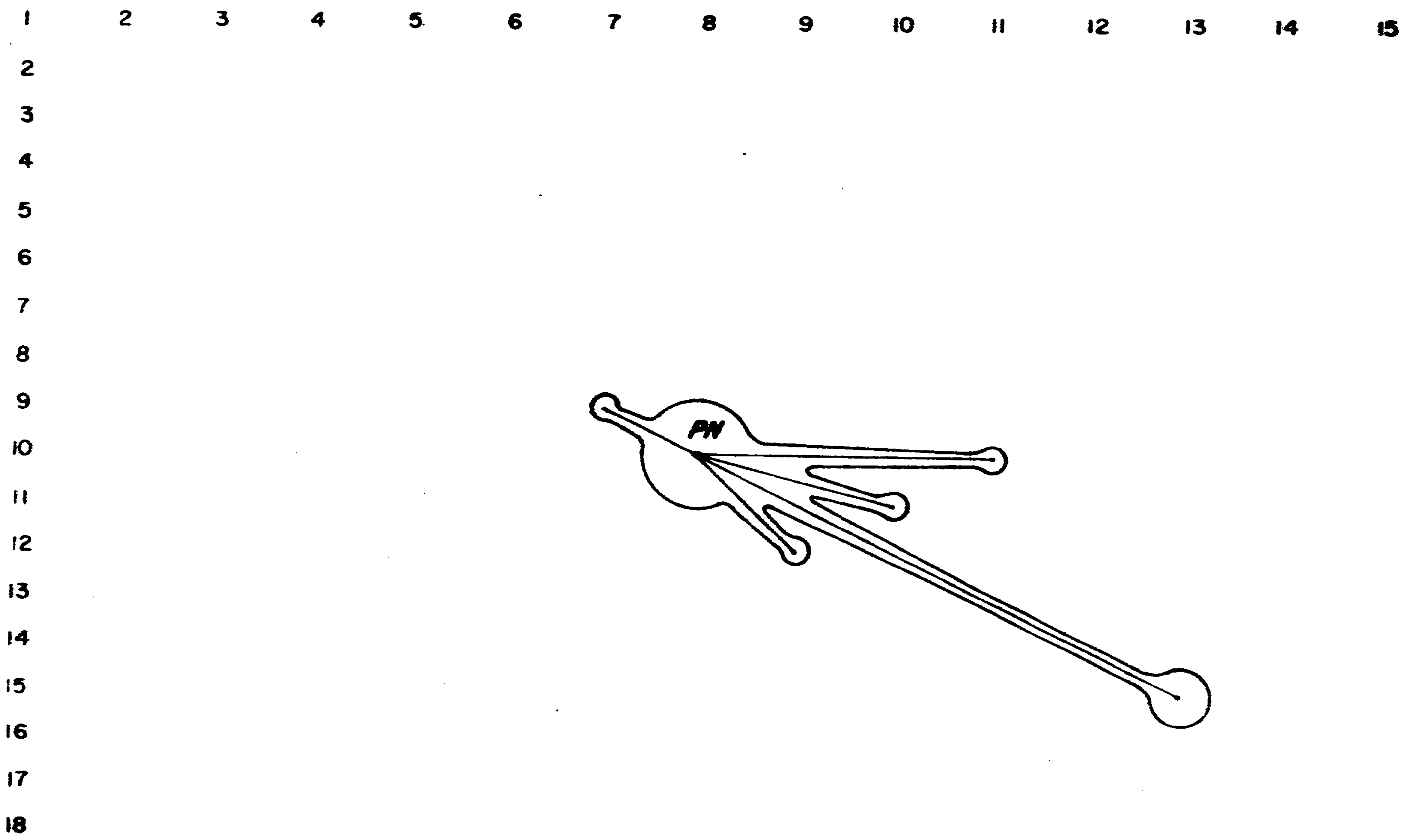


FIGURE 6

"Action Space in Behavioral Analysis"



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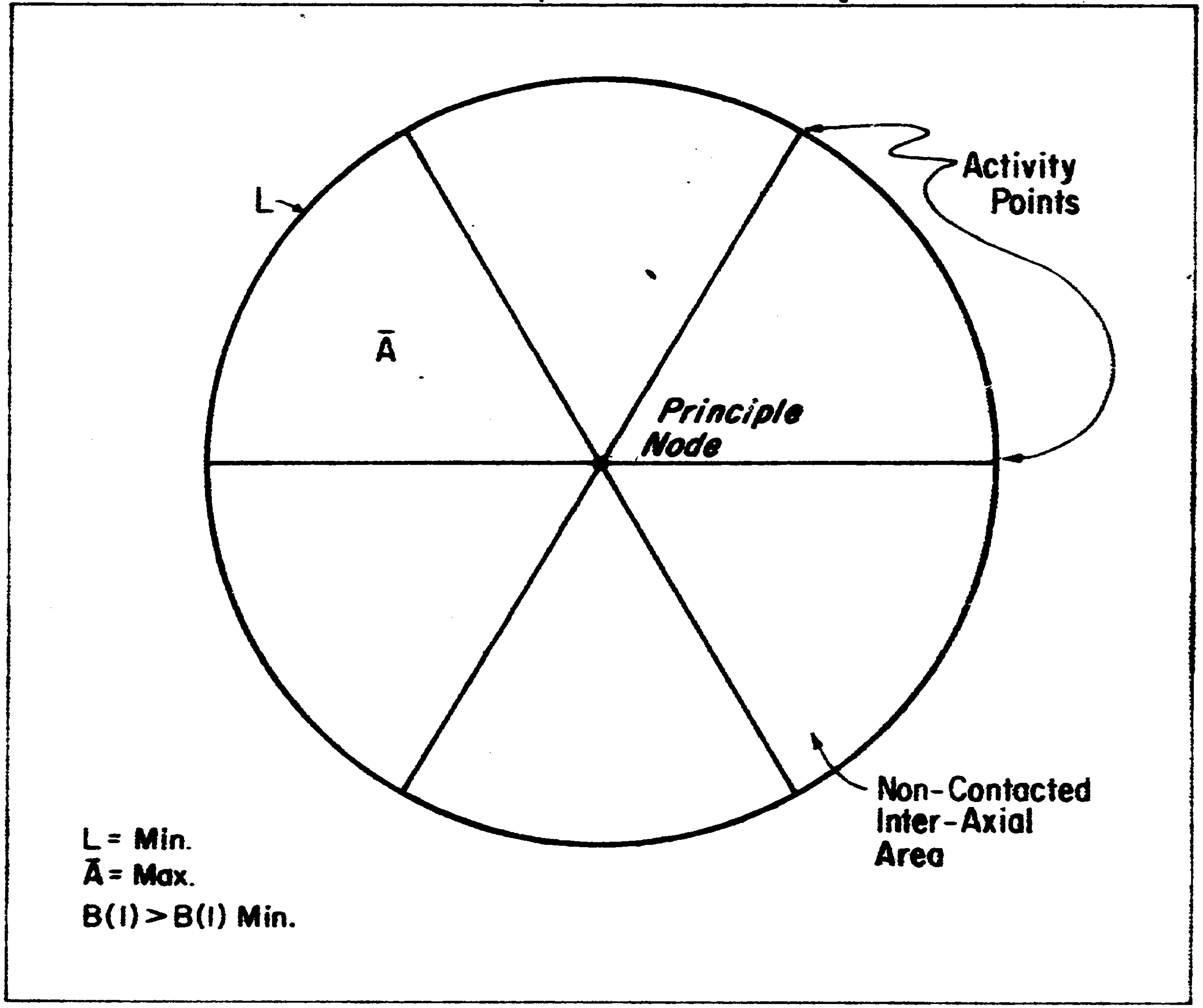

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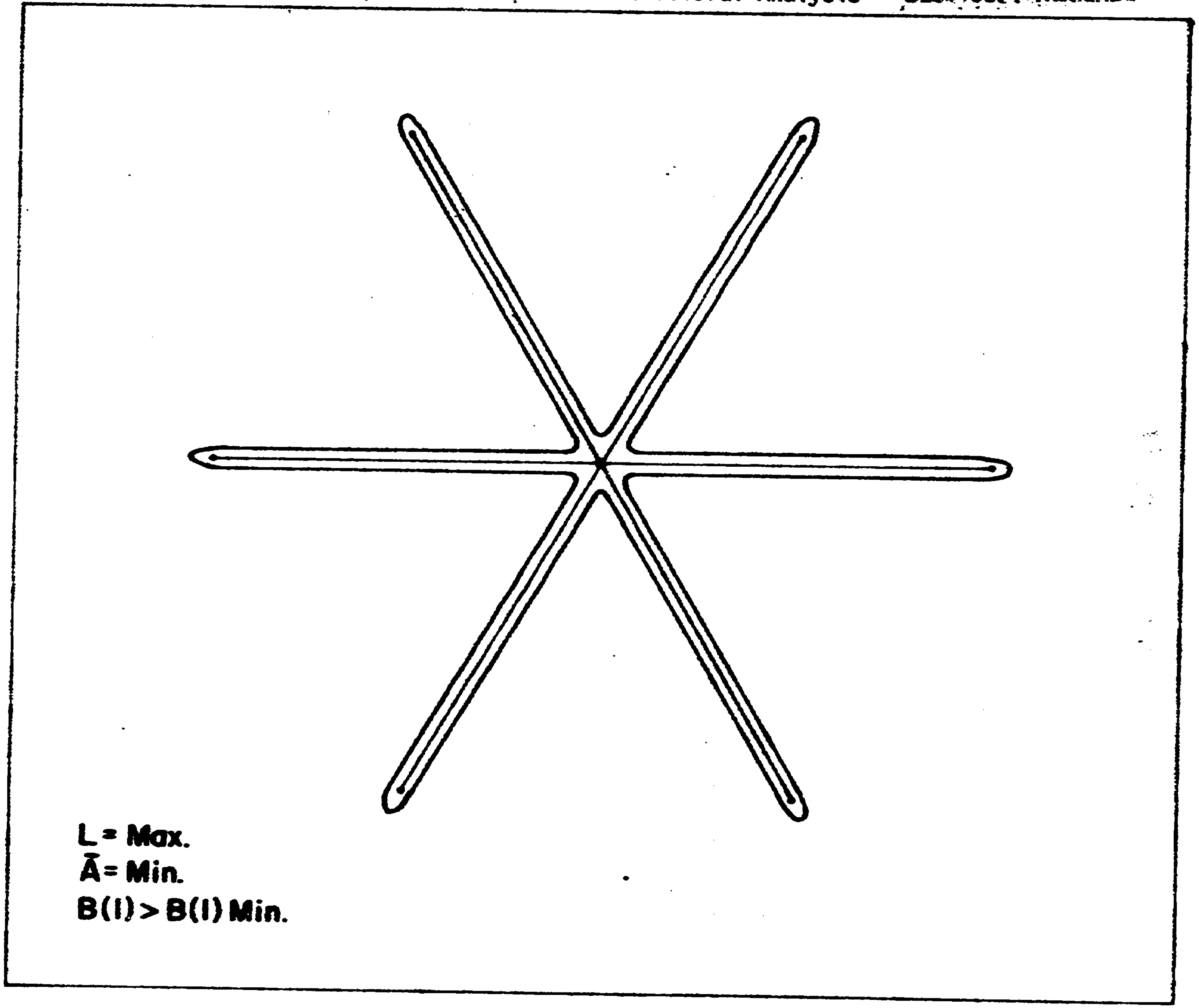
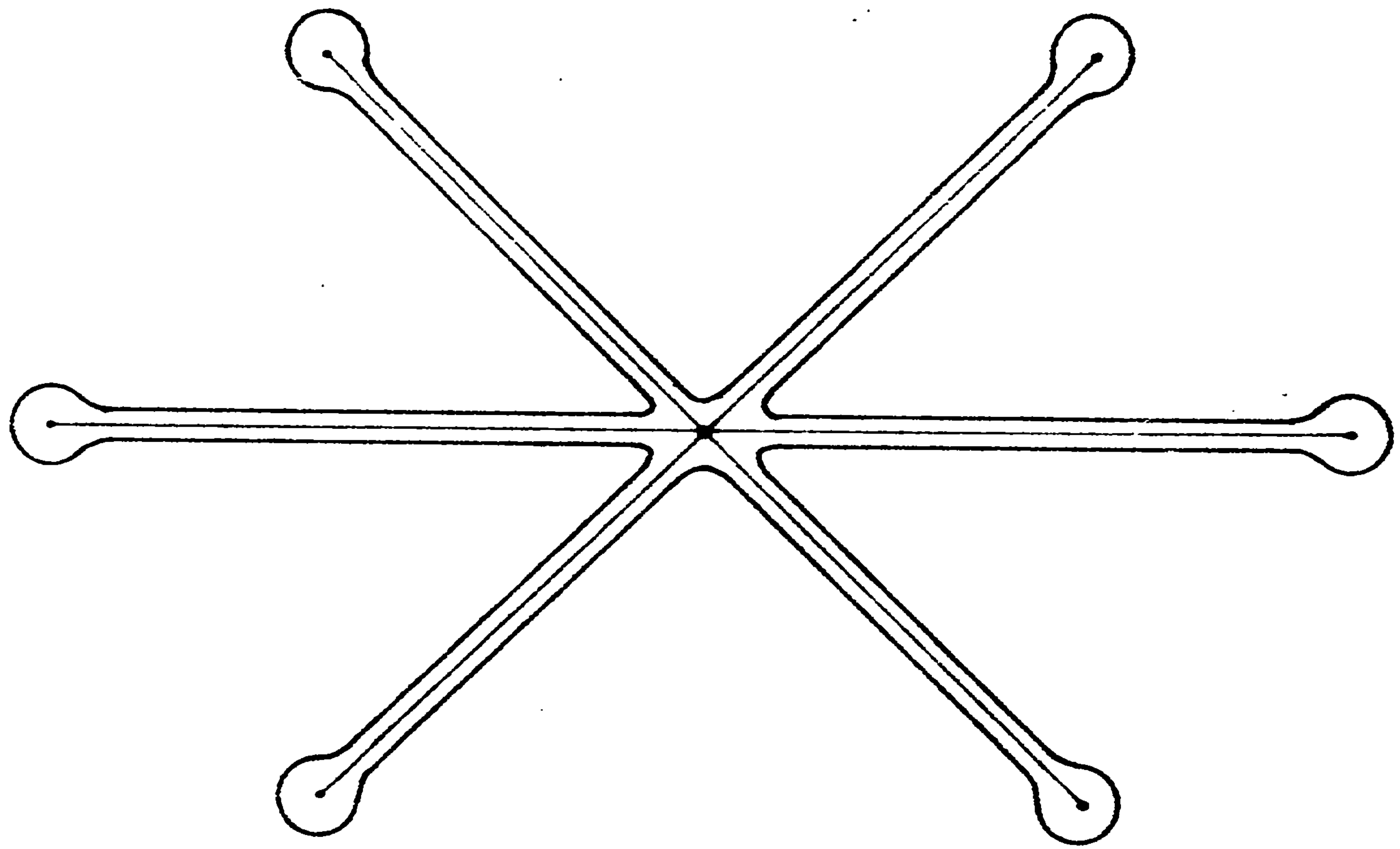


FIGURE 9 "Action Space in Behavioral Analysis" BEST COPY AVAILABLE



L ≠ Max. or Min.
A ≠ Min. or Max.
B(I) = B(I)Min.

FIGURE 10

"Action Space in Behavioral Analysis"

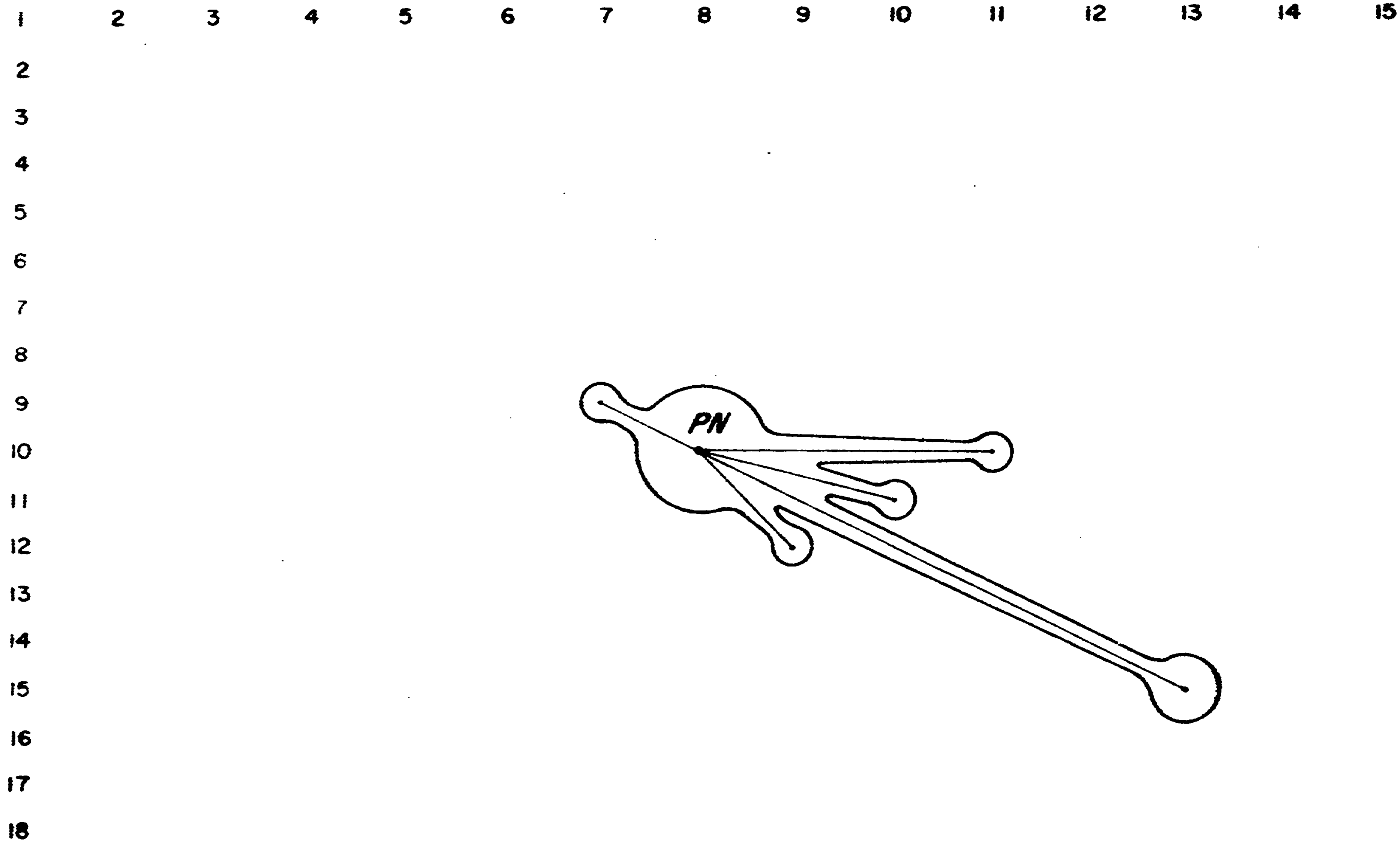


FIGURE 11 "Action Space in Behavioral Analysis"

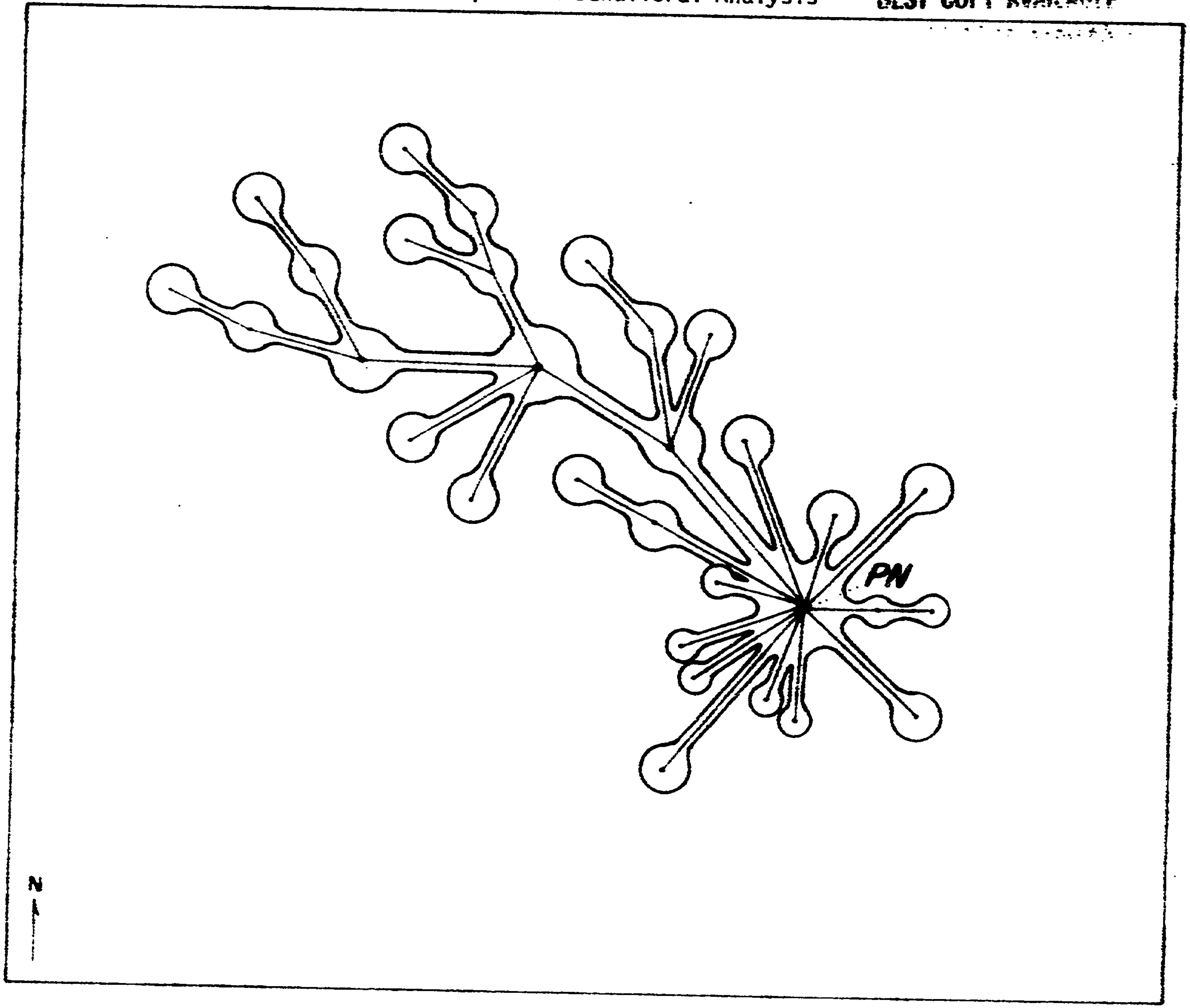


FIGURE 12 "Action Space in Behavioral Analysis" BEST COPY AVAILABLE

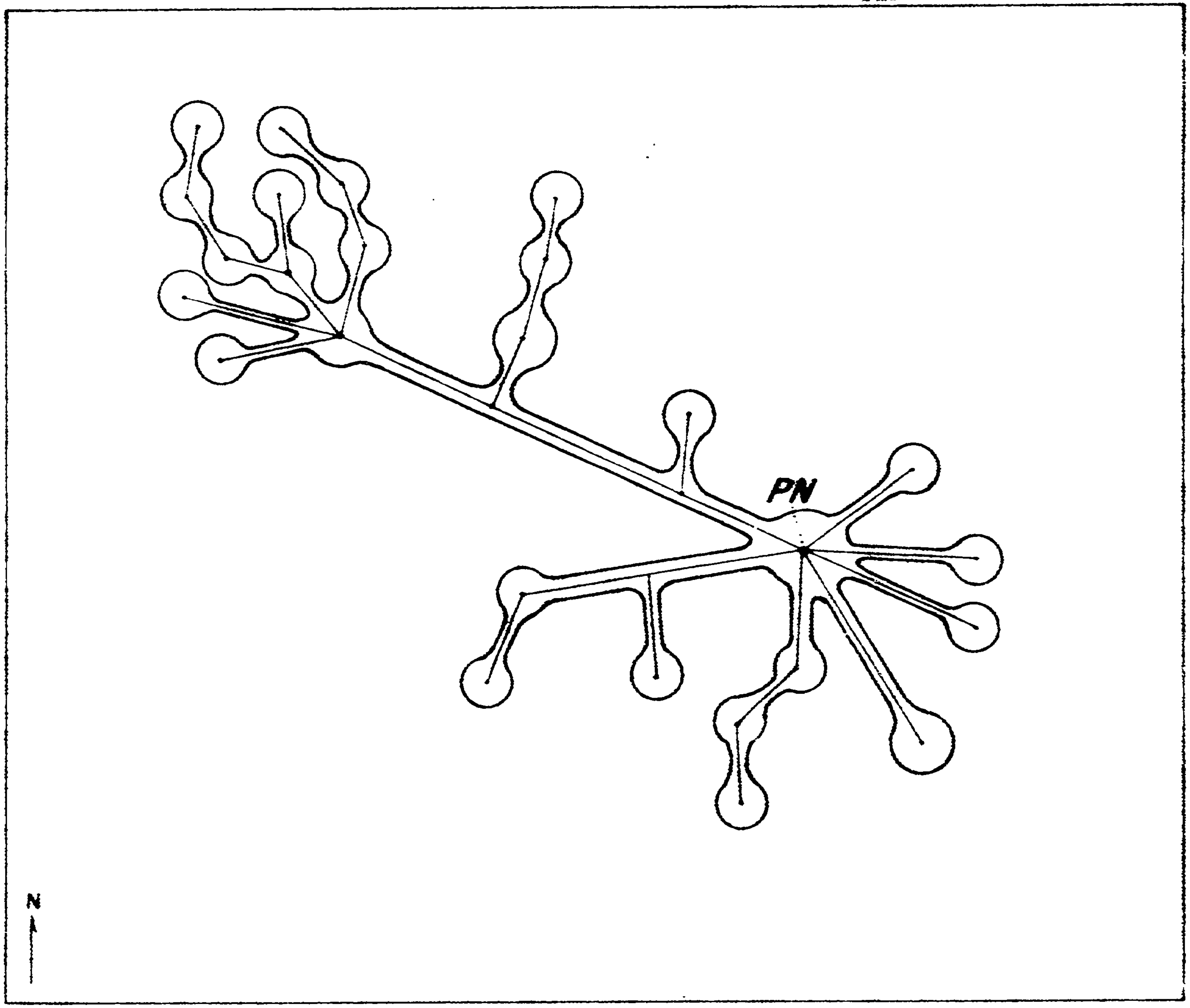


FIGURE 13 "Action Space in Behavioral Analysis"

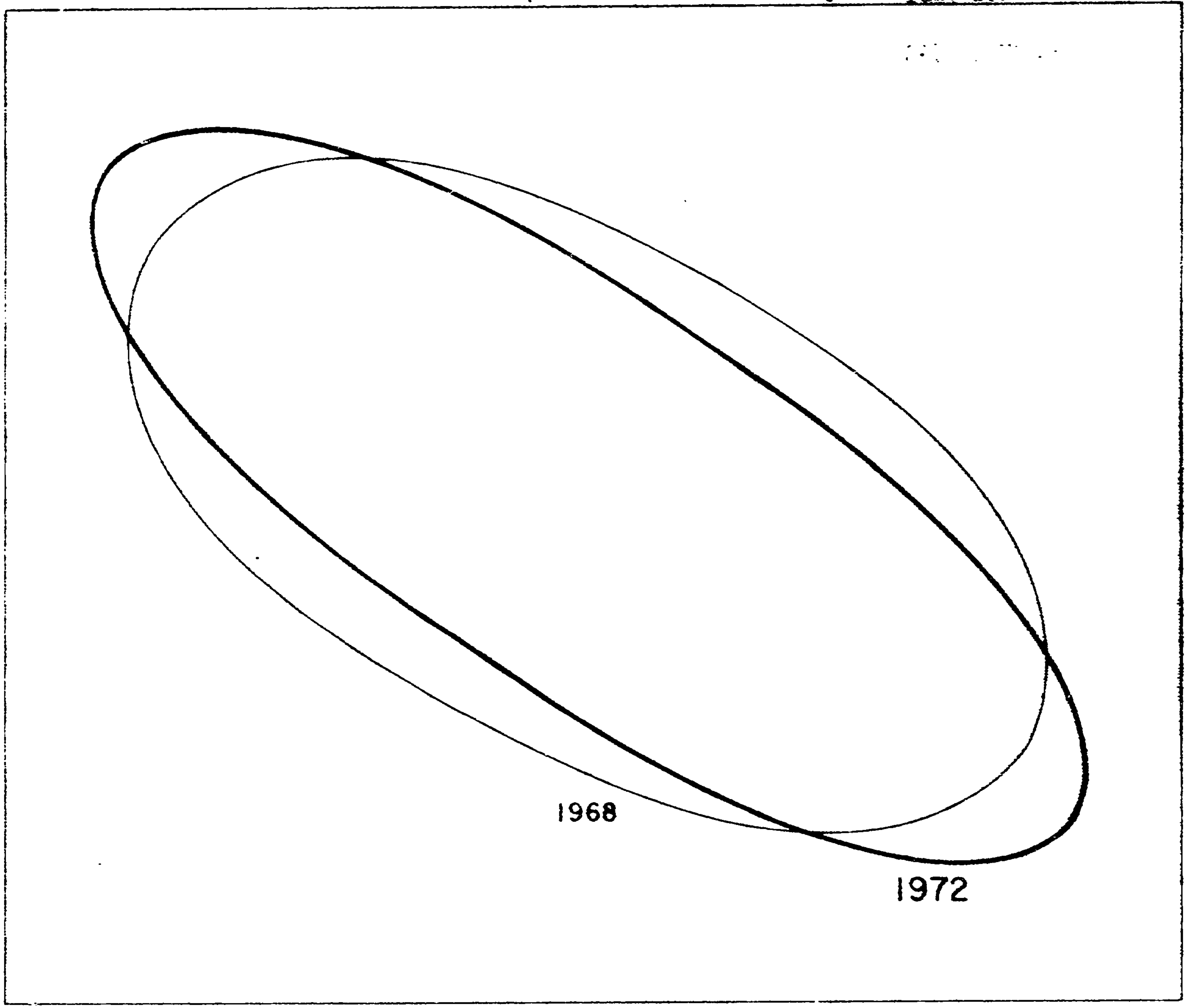


FIGURE 14 "Action Space in Behavioral Analysis" BEST COPY AVAILABLE

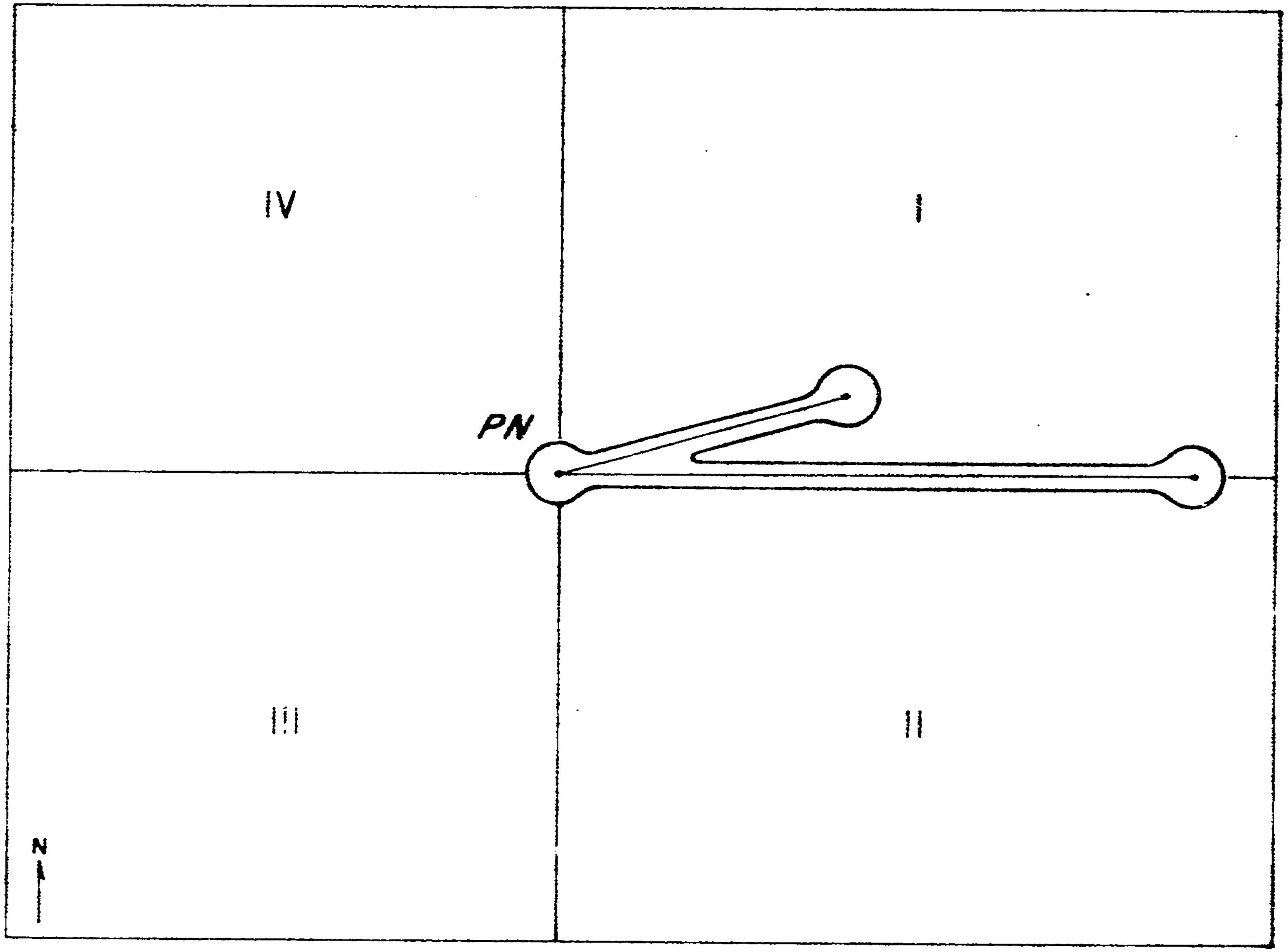


FIGURE CAPTIONS FOR
AN IMPLEMENTATION OF THE ACTION SPACE
CONCEPT OF BEHAVIORAL ANALYSIS

Fig. 1. Sets of existing, known and contacted points

Fig. 2. Sets of existing, known and contacted points with 2 discrete contact zones

Fig. 3. A hypothetical element pattern

Fig. 4. A hypothetical element pattern connected by transport corridors

Fig. 5. Basic five element activity pattern structure

Fig. 6. Basic five element action space

Fig. 7. First stage of iteration

Fig. 8. Final stage of iteration

Fig. 9. Optimum delineation of action space

Fig. 10. Actual measured contact action space

Fig. 11. Individual CAS, city of Chicago 1968

Fig. 12. Individual CAS, city of Chicago 1972

Fig. 13. Collective contact action spaces for 1968 and 1972

Fig. 14. CAS orientation and magnitude